CLAIMS

What is claimed is:

1. A movable microstructure comprising:

a first finger set comprising at least two first fingers extending substantially parallel to a first displacement axis;

a second finger set comprising at least one second finger, said at least one second finger extending substantially parallel to said first displacement axis, terminating between two first fingers, wherein each second finger is substantially closer to one of the two first fingers between which it terminates; and

an electrical circuit providing a position-dependent force having a magnitude varying in proportion to displacement along said first displacement axis.

2. The movable microstructure of claim 1 wherein said at least two first fingers comprise a conductive material, having a thickness between 2 and 100 microns, a width between 1 and 25 microns, a finger length between 2 to 50 microns, and an overlap length of more than 2 microns.

3. The movable microstructure of claim 2 wherein said at least one second finger comprises a conductive material, having a thickness between 2 and 100 microns, a width between 1 and 25 microns, a finger length between 2 to 50 microns, and an overlap length of more than 2 microns.

4. A movable microstructure comprising:

a substrate;

a proof-mass disposed above said substrate;

a first finger set comprising two or more first fingers affixed to said substrate and extending substantially parallel to a first displacement axis towards said proof-mass;

a second finger set comprising at least one second finger, each member of the second finger set extending substantially parallel to said first displacement axis from said proof-mass, terminating between two first fingers, wherein each second finger is substantially closer to one of the two first fingers between which it terminates, thereby forming a first capacitor; and

an electrical circuit providing a voltage across said capacitor to provide a position-dependent force on said proof-mass, said position-dependent force having a component along an axis substantially orthogonal to said first displacement axis, the magnitude of said position-dependent force varying in proportion to displacement along said first displacement axis.

5. The movable microstructure of claim 4 further including an oscillation-sustaining feedback loop having an output representative of proof-mass movement along said first displacement axis, said oscillation-sustaining feedback loop using electrostatic forces to sustain oscillatory motion.

6. The movable microstructure of claim 5 further including:

a capacitive bridge responsive to displacements of said proof-mass along an axis orthogonal to said first displacement axis; and

a position sense interface connected to said capacitive bridge, said position sense interface having an electrical output varying in response to changes in said capacitive bridge.

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7. The movable microstructure of claim 5 wherein the voltage applied to said first capacitor is substantially constant and chosen to cause said vibrating mass, absent a Coriolis force, to vibrate more precisely along said first axis.

8. The movable microstructure of claim 6 further including:

a quadrature detection circuit having an output, said quadrature detection circuit synchronized with the output of said oscillation-sustaining feedback loop; and

a feedback connection from the output of said quadrature detection circuit to said first capacitor, said feedback connection providing a voltage across said first capacitor;

wherein said voltage causes the average output of said quadrature detection circuitry to converge towards a constant value, thereby causing said mass to vibrate, absent a Coriolis force, more precisely along said first axis.

9. The movable microstructure of claim 4 further including:

a third finger set comprising two or more third fingers affixed to said substrate and extending substantially parallel to a first displacement axis towards said proof-mass; and

a fourth finger set comprising at least one fourth finger, each member of the fourth finger set extending substantially parallel to said first displacement axis from said proof-mass along a direction opposite the direction of extension of said second fingers, terminating between two third fingers, wherein each fourth finger is closer to one of the two third fingers between which it terminates, thereby forming a second capacitor.

10. The moveable microstructure of claim 9 wherein said electrical circuit provides a voltage across said second capacitor to provide a position-dependent force on said proof-mass, said position-dependent force having a component along an axis substantially orthogonal to said first displacement axis, the magnitude of said position-dependent force varying in proportion to displacement along said first displacement axis.

11. The moveable microstructure of claim 9 further including an electrical circuit providing a voltage across said second capacitor to provide a position-dependent force on said proof-mass, said position-dependent force having a component along an axis substantially orthogonal to said first displacement axis, the magnitude of said position-dependent force varying in proportion to displacement along said first displacement axis.

12. The movable microstructure of claim 9 further including:

a capacitive bridge responsive to displacements of said proof-mass along a sense axis orthogonal to said first displacement axis;

a position sense interface connected to said capacitive bridge, said position sense interface having an electrical output varying in response to changes in said capacitive bridge;

a quadrature detection circuit having an output, said quadrature detection circuit synchronized with the output of said oscillation-sustaining feedback loop;

a feedback connection from the output of said quadrature detection circuit to said first and second capacitors, said feedback connection providing a defined voltage across each of said first and second capacitors, said voltage causing the average output of said quadrature detection circuitry to converge towards a constant value, thereby causing said mass to vibrate, absent a Coriolis force, more precisely along said first axis; and

a Coriolis detection circuit having an output, said Coriolis detection circuit synchronized with the output of said oscillation-sustaining feedback loop;

wherein the Coriolis detection circuit output provides an electrical signal representative of rotational motion about an axis largely orthogonal to both said sense axis and said first displacement axis.

13. A movable microstructure comprising:

a substrate;

a first proof-mass disposed above said substrate;

a second proof-mass disposed above said substrate;

a first finger set comprising two or more first fingers affixed to said substrate and extending substantially parallel to a first displacement axis towards said first proof-mass;

a second finger set comprising at least one second finger, each member of the second finger set extending substantially parallel to said first displacement axis from said first proof-mass, terminating between two first fingers, wherein each second finger is closer to one of the two first fingers between which it terminates, thereby forming a first smaller gap and a first capacitor;

a third finger set comprising two or more third fingers affixed to said substrate and extending in a direction opposite said first finger set and substantially parallel to said first displacement axis towards said second proof-mass;

a fourth finger set comprising at least one fourth finger, each member of the fourth finger set extending substantially parallel to said first displacement axis from said second proof-mass, along a direction opposite said second fingers, terminating between two third fingers, wherein each fourth finger is closer to one of the two third fingers between which it

terminates, thereby forming a second smaller gap and a second capacitor; and

an electrical circuit providing a first voltage across said first capacitor, and a second voltage across said second capacitor to provide position-dependent forces on said first proof-mass and on said second proof-mass, said position-dependent forces having a component along an axis substantially orthogonal to said first displacement axis, the magnitude of said position-dependent force varying in proportion to proof-mass displacement along said first displacement axis.

14. The movable microstructure of claim 13 further including an oscillation-sustaining feedback loop having an output representative of the relative movement between said first proof-mass and said second proof-mass along said first displacement axis, said oscillation-sustaining feedback loop using electrostatic forces to sustain oscillatory motion.

15. The movable microstructure of claim 14 further including:

a capacitive bridge responsive to the relative displacement between said first proof-mass and said second proof-mass along an axis orthogonal to said first displacement axis; and

a position sense interface connected to said capacitive bridge, said position sense interface having an electrical output varying in response to changes in said capacitive bridge.

16. The movable microstructure of claim 14 wherein said first voltage and said second voltage are distinct, are substantially constant, and are chosen to cause said vibrating mass, absent a Coriolis force, to vibrate more precisely along said first axis.

17. The movable microstructure of claim 15 further including:

a quadrature detection circuit having an output, said quadrature detection circuit synchronized with the output of said oscillation-sustaining feedback loop; and

a feedback connection from the output of said quadrature detection circuit to said first capacitor and said second capacitor, said feedback connection providing said first voltage and said second voltage;

wherein said first voltage and said second voltage cause the average output of said quadrature detection circuitry to converge towards a constant value, thereby causing said mass to vibrate, absent a Coriolis force, more precisely along said first axis.

18. The movable microstructure of claim 14 further including:

a fifth finger set comprising two or more fifth fingers affixed to said substrate and extending substantially parallel to a first displacement axis towards said first proof-mass in the direction of said first fingers;

a sixth finger set comprising at least one sixth finger, each member of the sixth finger set extending substantially parallel to said first displacement axis from said first proof-mass along the direction of extension of said second fingers, terminating between two fifth fingers, wherein each sixth finger is substantially closer to the fifth finger opposite in direction of said first smaller gap in relation to said second finger, thereby forming a third capacitor;

a seventh finger set comprising two or more seventh fingers affixed to said substrate and extending substantially parallel to a first displacement axis and towards said second proof-mass;

an eighth finger set comprising at least one eighth finger, each member of the eighth finger set extending substantially parallel to said first displacement axis from said second proof-mass opposite the direction of the second fingers, terminating between two seventh fingers, wherein each eighth finger is substantially closer to the seventh finger opposite in direction of said second smaller gap in relation to said fourth finger, thereby forming a fourth capacitor; and

an electrical circuit providing a third voltage across said third capacitor, and a fourth voltage across said fourth capacitor to provide position-dependent forces on said first proof-mass and on said second proof-mass, said position-dependent forces having a component along an axis substantially orthogonal to said first displacement axis, the magnitude of said position-dependent force varying in proportion to proof-mass displacement along said first displacement axis.

19. The movable microstructure of claim 18 further including:

a capacitive bridge responsive to the relative displacement between said first proof-mass and said second proof-mass along an axis orthogonal to said first displacement axis;

a position sense interface connected to said capacitive bridge, said position sense interface having an electrical output varying in response to changes in said capacitive bridge;

a quadrature detection circuit having an output, said quadrature detection circuit synchronized with the output of said oscillation-sustaining feedback loop;

a feedback connection from the output of said quadrature detection circuit to said first capacitor, said second capacitor, said third capacitor and said fourth capacitor, said feedback connection providing said first voltage, said second voltage, said third voltage and said fourth voltage; and

a Coriolis detection circuit having an electrical signal output representative of rotational motion about an axis largely orthogonal to both said sense axis and said first displacement axis, said Coriolis detection circuit synchronized with the output of said oscillation-sustaining feedback loop.

20. A micromachined vibratory rate gyroscope comprising:

a substrate;

a proof-mass disposed above said substrate;

a first finger set comprising two or more first fingers affixed to said substrate and extending substantially parallel to a first displacement axis towards said proof-mass;

a second finger set comprising at least one second finger, each member of the second finger set extending substantially parallel to said first displacement axis from said proof-mass, terminating between two first fingers, wherein each second finger is substantially closer to one of the two first fingers between which it terminates, thereby forming a capacitor;

an oscillation-sustaining feedback loop having an output representative of proof-mass movement along said first displacement axis;

a capacitive bridge responsive to displacements of said proof-mass along an axis orthogonal to said first displacement axis;

a position sense interface connected to said capacitive bridge, said position sense interface having an electrical output varying in response to changes in said capacitive bridge;

a quadrature detection circuit having an output, said quadrature detection circuit synchronized with the output of said oscillation-sustaining feedback loop; and

a feedback connection from the output of said quadrature detection circuit to said capacitor, said feedback connection providing a voltage across said first capacitor;

wherein the voltage applied to said capacitor drives the output of said quadrature detection circuitry towards a constant value, thereby causing said mass to vibrate absent a Coriolis force, more precisely along said first axis.